Advanced Collaboration Environments and Scientific Workplaces of the Future

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Outline

- Introduction and Collocation
- Presence and Immersion
- Sharing and Coordination
- Persistence and Asynchrony
- Group Oriented Interfaces
- Networking and Communication
- Systems Architecture
- Access Grid Project
- Scientific Workplace of the Future
- Network Services for the Access Grid
- References

Radical Collocation

- Experts/domain specialists physically located within a single work place (i.e. Project Room) for the duration of a project (one week to a few months)
- Examples: space mission control, emergency situation rooms, operating theatres, automotive repair shop, trading floors, etc.
- Benefits of Collocation
  - Constant real-time visual and audio communication is possible
  - Ad hoc sub grouping is possible
  - Multiple simultaneous conversations possible
  - Ad hoc sharing of documents, workstations and applications
  - Complex shared context is created in situ
  - Large amount of shared work state is made persistent

Benefits of Radical Collocation

- Suggested productivity gains
  - 2x-10x depending on task
  - Higher quality output
  - Fewer changes overtime
  - Better and faster decisions
- (RC) Recently used to:
  - Annotate new genome data at Celera
  - Design NASA space missions at JPL
  - Evaluate fusion reactor designs at Snowmass

Radical Collocation and Visualization

- Understanding the output of large-scale computational science runs is typically a group task
- Often all experts are not local to one site
- Analysis takes place over several days to weeks
- Complex multi person problem solving strategies often are required to understand and validate the simulation output
- Large-scale computing work naturally fits into campaigns of multiple weeks per problem with breathers in between
- Large-scale Scientific Visualization is an ideal testbed for advanced collaboration technology research

Virtual (Radical) Collocation

- Can we create the benefits of radical collocation without the need for people to be physically collocated?
- What aspects of collocation are critical to enable high group productivity?
- What digital technologies can be used to provide the benefits without high costs?
- Can we go beyond the classical collocation model to derive productivity benefits in excess of those from physical collocation?

Advanced Collaboration Environments

- Goals:
  - Use advanced computer mediated communications techniques to enhance work environments to enable increased productivity for collaborative work.
  - Exploit the use of high-performance computing technologies (digital media, advanced networking, visualization, VR, etc.) to improve the effectiveness of large-scale collaborative work environments.
  - Thoroughly investigate the thesis that network based advanced collaboration technology can create groupwork productivity benefits comparable to that of radical (classical) collocation for distributed work.

Presence and Immersion [1]

- Presence
  - Concept originally concerned notion of Tele-presence
    - Remote operation of equipment
    - Remote exploration and task oriented work (e.g. planets, ocean floor, hazardous areas, surgery)
  - The “sensation of being there”
    - Recreate the sensory inputs of a remote location
    - Match modalities with human sensory/perception
    - Transmit over a network (latency, bandwidth)
    - Provide natural way to interact with the remote location
  - Achieving a sense of presence is a key human factor in the effectiveness of remotely piloted vehicles, tele-robotics, etc.

Presence and Immersion [2]

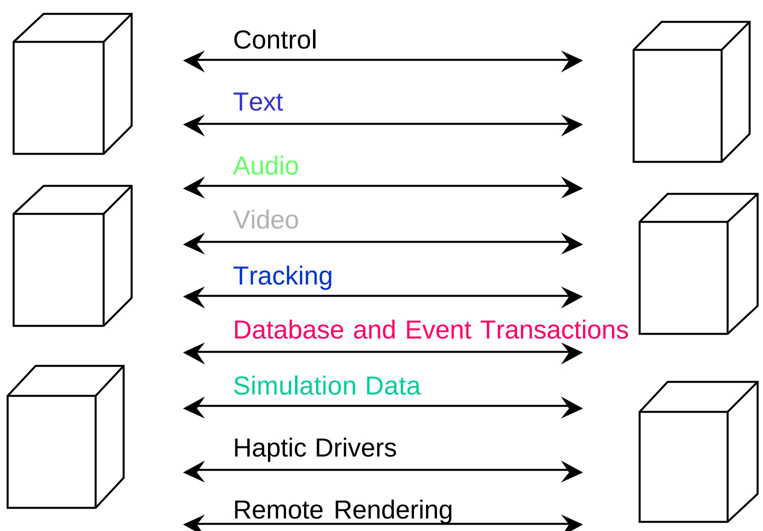
- In 1980's researchers began to consider presence as a concept useful for understanding the effectiveness of collaborative environments
  - Sara Bly's work at Xerox and others
  - A sense of presence seems to be related to sense of co-location for tele-collaboration
  - Psycho-physical phenomena of presence is not yet fully understood
- Most researchers studying presence are focused on understanding the non-social interaction with computer mediated representation of a remote environment (or VR recreation of a non-social space)

Presence and Immersion [3]

- A users sense of presence depends on:
  - Coupling communications channels to sensory modalities
  - Fidelity of the communications channels
    - Low latency/lag and high-bandwidth (matched to sensory needs)
  - The degree of immersion achieved
    - Transparency of the human-computer interfaces
    - The completeness of the re-created the world
    - High-degree of task involvement improves sense of immersion
- High-degree of Immersion $\Rightarrow$ increased presence
- High presence $\Rightarrow$ increased sense of collocation
- Tele-Immersion combined notions of Tele-Presence and Immersion to indicate use of VR over networks

Tele-Immersion Networking Requirements

Type	Latency	Bandwidth	Reliable	Multicast	Security	Streaming	DynQos
Control	*< 30 ms*	64Kb/s	*Yes*	No	*High*	No	Low
Text	*< 100 ms*	64Kb/s	*Yes*	No	Medium	No	Low
Audio	*< 30 ms*	Nx128Kb/s	No	*Yes*	Medium	*Yes*	Medium
Video	*< 100 ms*	Nx5Mb/s	No	*Yes*	Low	*Yes*	Medium
Tracking	*< 10 ms*	Nx128Kb/s	No	*Yes*	Low	*Yes*	Medium
Database	*< 100 ms*	*> 1GB/s*	*Yes*	Maybe	Medium	No	*High*
Simulation	*< 30 ms*	*> 1GB/s*	Mixed	Maybe	Medium	Maybe	*High*
Haptic	*< 10 ms*	> 1 Mb/s	Mixed	Maybe	High	Maybe	*High*
Rendering	*< 30 ms*	*>1GB/s*	No	Maybe	Low	Maybe	Medium



- Immersive environment
- Sharing of objects and virtual space
- Coordinated navigation and discovery
- Interactive control and synchronization
- Interactive modification of environment
- Scalable distribution of environment

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Sharing and Coordination [1]

- Sharing: to enable two or more people to access a document, application, resource or interface
  - synchronous or asynchronous
  - read-write (local/global) or read-only
  - guided or un-guided
  - course grain or fine-grain, etc.
- Sharing mechanisms and policies determines what and where_something is shared
- Coordination policies and mechanisms determine who is permitted to share and how sharing is accomplished

Sharing and Coordination [2]

- Coordination: to manage the interactions of two or more people as they share an object
  - Access control and permissions (sharing)
    - person X has access rights to object α
  - Floor control (coordinating)
    - Person X can access and object α now
- Both sharing and coordinating need a common security and authentication model
  - Establishing identity
  - Establishing trust relationships

Sharing and Coordinating [3]

- Use of strong metaphors (e.g. spatial)
  - Provide organizing principles for the system
    - How resources are organized and presented to the user
    - How resources and users interact with each other
  - Enable people to use innate knowledge to:
    - Construct a conceptual model of the system
      - Navigating through the environment
      - Finding things and people
      - Easily learn the rules of interaction
    - Users help each other through common knowledge
      - System behaves the same for each user
  - Enables testing of orthogonality of function/behaviors

Persistence and Asynchrony [1]

- Persistence: the property of always being there, independent of use or user connectivity
  - Can be applied to:
    - Names, users and services
    - Shared objects, applications and interfaces
  - Enables static description of a base of available resources and services (publishing)
  - Enables users to extend the environment by building on persistent resources (outfitting)
  - Improves navigation and resource management (scheduling and reservations)

Persistence and Asynchrony [2]

- Synchronous collaboration
  - Real-time interactions, two-way fine grain communication
  - Ad hoc and unstructured communication patterns
  - Examples: real-time video and audio, chat, real-time application sharing
- Asynchronous collaboration
  - Non-real time interactions, course grain communication
  - More structured communications patterns
  - Examples: email, annotation of papers, recorded video, voice mail, etc.

Persistence and Asynchrony [3]

- Both forms of communication are required to support flexible collaboration
- Persistence coupled with spatial metaphors (consistent with the project room concept) provide a base for supporting asynchronous interactions through “left objects” (messages in time)
- Recording and playback technologies enable arbitrary capture of content for asynchronous use (voyager m-point system)
- Annotation and synchronization tools are needed to compliment the recording/playback environments (examples)

Group Oriented Systems [1]

- Scientific computing collaborations are often composed of small teams interacting with multiple other small teams
  - Typical teams (2-10 persons)
  - Typical scientific collaboration (2-8 teams)
- Large-scale experimental science can be much bigger (e.g. HEP, space science)
- Biology and Nanoscience collaborations tend to be slightly smaller
- The needs of small groups are different from the needs of individuals

Group Oriented Systems [2]

- Collaborations composed of multiple groups introduce the need for hierarchy into the collaboration environment
  - Team ⇔ Group ⇔ Individual
  - Influences many things
    - Displays and room layout
    - Audio performance and coverage
    - Sharing and coordination protocols
    - Security and authentication
    - Interfaces and tools

Group Oriented Systems [3]

- Scaled up desktop collaboration systems are inadequate to meet the needs of groups
  - Typically no support for hierarchy
  - Simple security and sharing models
  - Human factors not well addressed
- Need systems designed to address the unique requirements of groups that need to collaborate with a small number of other groups
- Note that this is a subset of the Radical Collocation problem
- Individual integration with group oriented systems

Networking and Communications [1]

- Requirements for networking
  - Low WAN latency (< 10 ms needed for some things)
  - High-bandwidth (multiple gigabit channels)
  - Scalable m-way broadcast mechanism (multicast, both reliable and unreliable delivery)
  - Low latency streaming media protocols (RTP, RTCP)
  - Scalable security model (PKI, GSI)
  - Scalable bandwidth model (MPLS, DWDM)

Access Grid $\Rightarrow$ Integrating Group to Group Collaboration and Immersion

Related Work:

- Berkeley and LBNL’s Mbone Tools (Jacobson et al.)
- Xerox PARC MOO and Jupiter Projects (Curtis, et. al.)
- Argonne/NEU’s Labspace Project (Evard/Stevens et. al.)
- EVL’s CAVERsoft (DeFanti, et. al.)
- UNC’s Office of the Future (Fuchs et. al.)
- DOE’s Collaboratory Pilots (Zalusec et. al.)

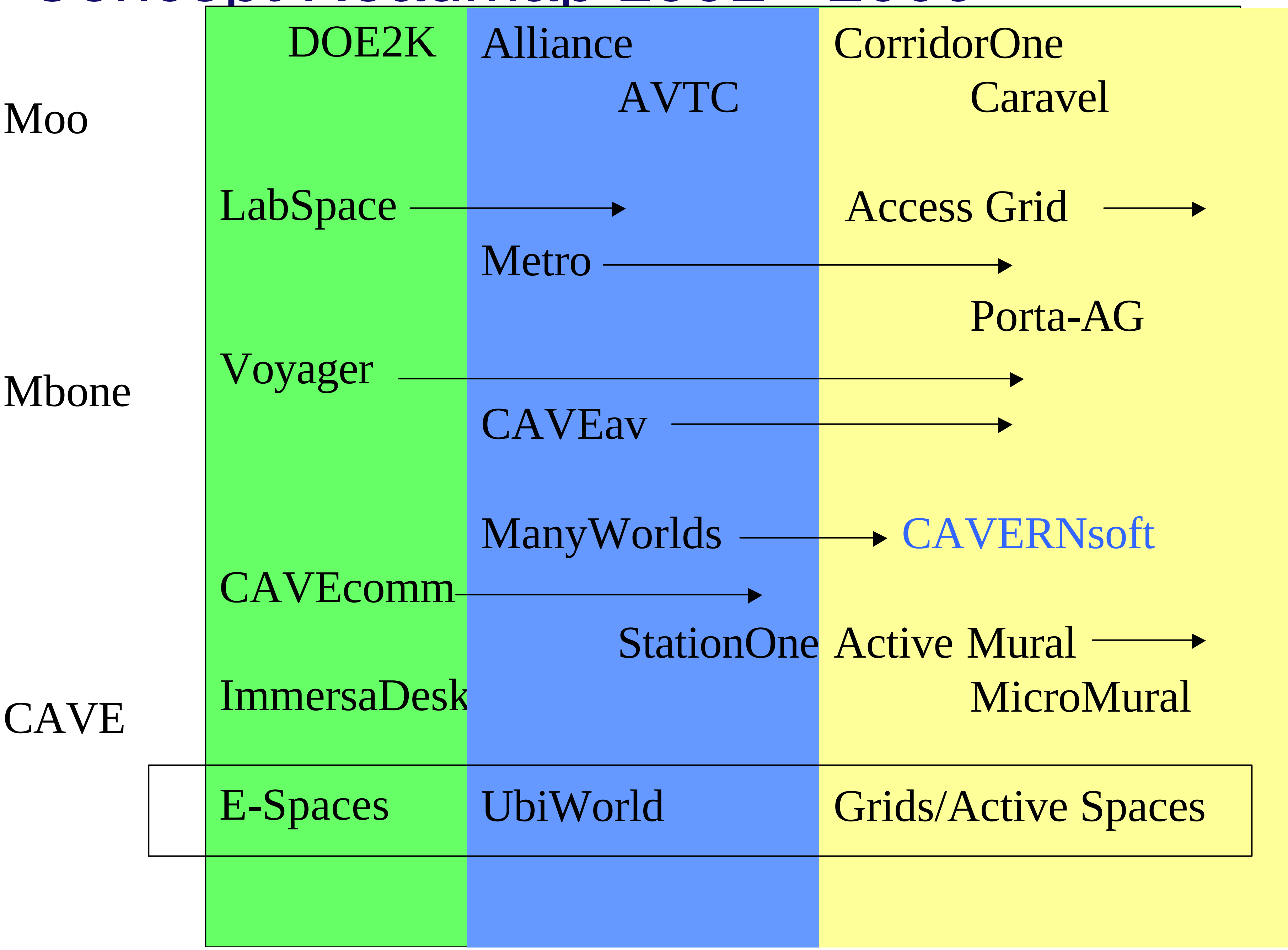
Stages of Collaborative Work

- Awareness
- Interaction
- Cooperation
- Collaboration
- Virtual Organization

Increasing need for persistent collaborative infrastructure

Can adding the concept of Persistent Shared Spaces to the current suite of computer supported collaborative work tools enable the cost-effective support of virtual organizations.

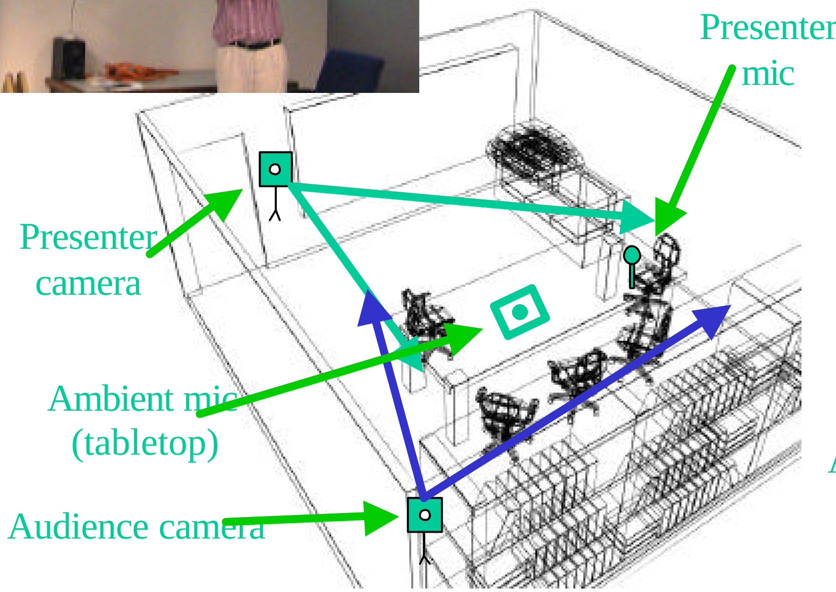
Concept Roadmap 1992 - 2000

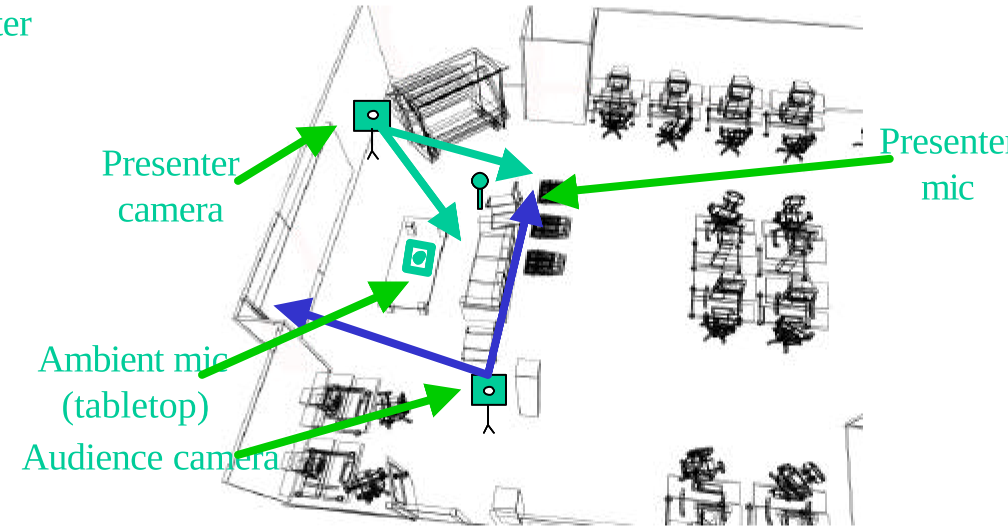


Access Grid Project Goals

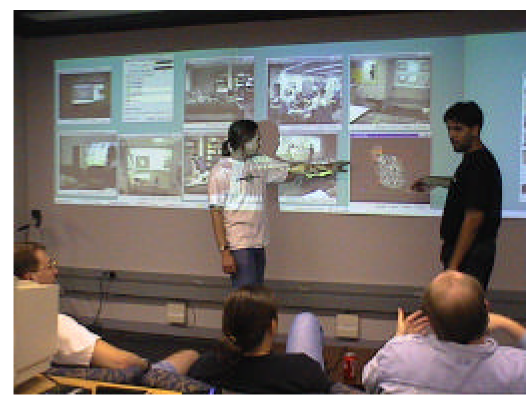
- Enable Group-to-Group Interaction and Collaboration
  - Connecting People and Teams via the Grid
- Improve the User Experience: Go Beyond Teleconferencing
  - Provide a Sense of Presence
  - Support Natural Interaction Modalities
- Use Quality but Affordable Digital IP Based Audio/video
  - Leverage IP Open Source Tools
- Enable Complex Multisite Visual and Collaborative Experiences
  - Integrate With High-end Visualization Environments
  - ActiveMural, Powerwall, CAVE Family, Workbenches
- Build on Integrated Grid Services Architecture
  - Develop New Tools Specifically Support Group Collaboration

Access Grid Nodes





- Access Grid Nodes Under Development
  - Library, Workshop
  - ActiveMural Room
  - Office
  - Auditorium



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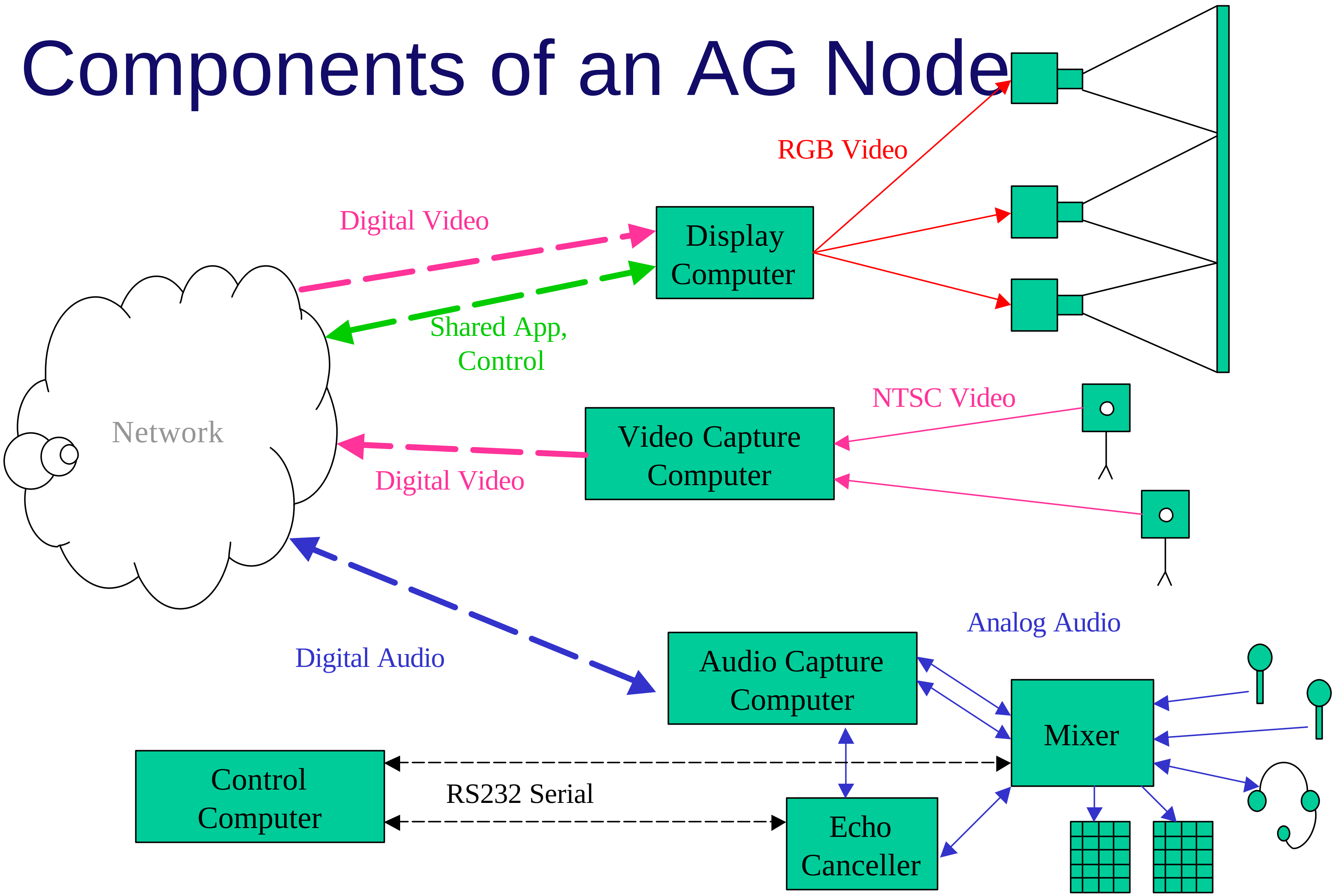
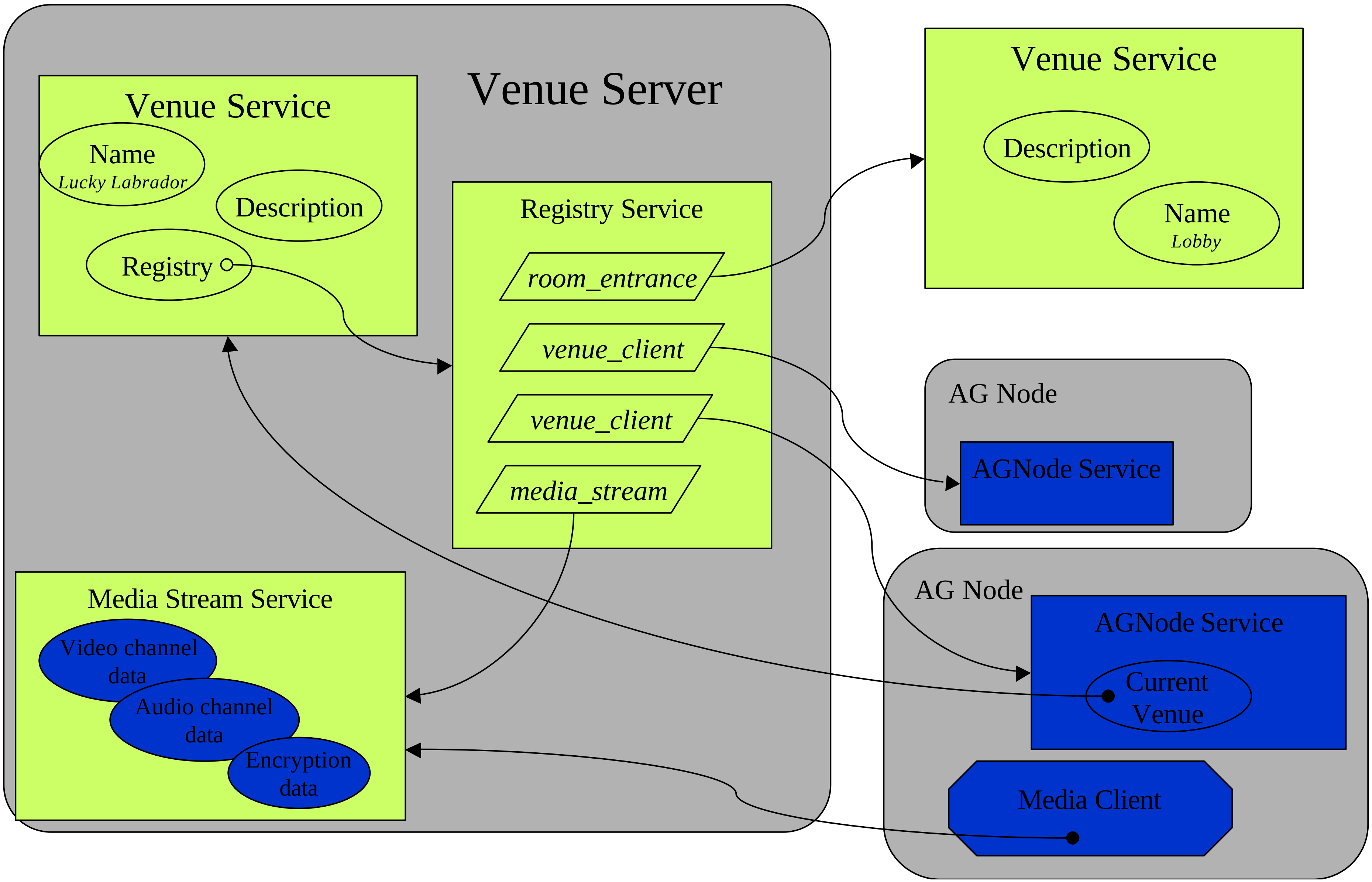
Components of an AG Node



AG Systems Architecture [1]

- Virtual Venues
  - Spatial metaphor and resource organization
  - Access control and services management
- AG Nodes/Clients
  - Edge device management, user interfaces and clients
  - Gateway services to room oriented resources
- Network Services
  - Stream processing and network management
- Applications
- Grid Services

VV 2.0 Services Architecture



Virtual Venues Server

- Venues service
  - Venue name, description
  - Registry
- Venues registry is the “heart” of the venue
- Mechanism for spatial scoping
- Services bound to the venue are registered here
- Default access control policy:
  - Any client with access to the Venues service has access to the services registered in its registry

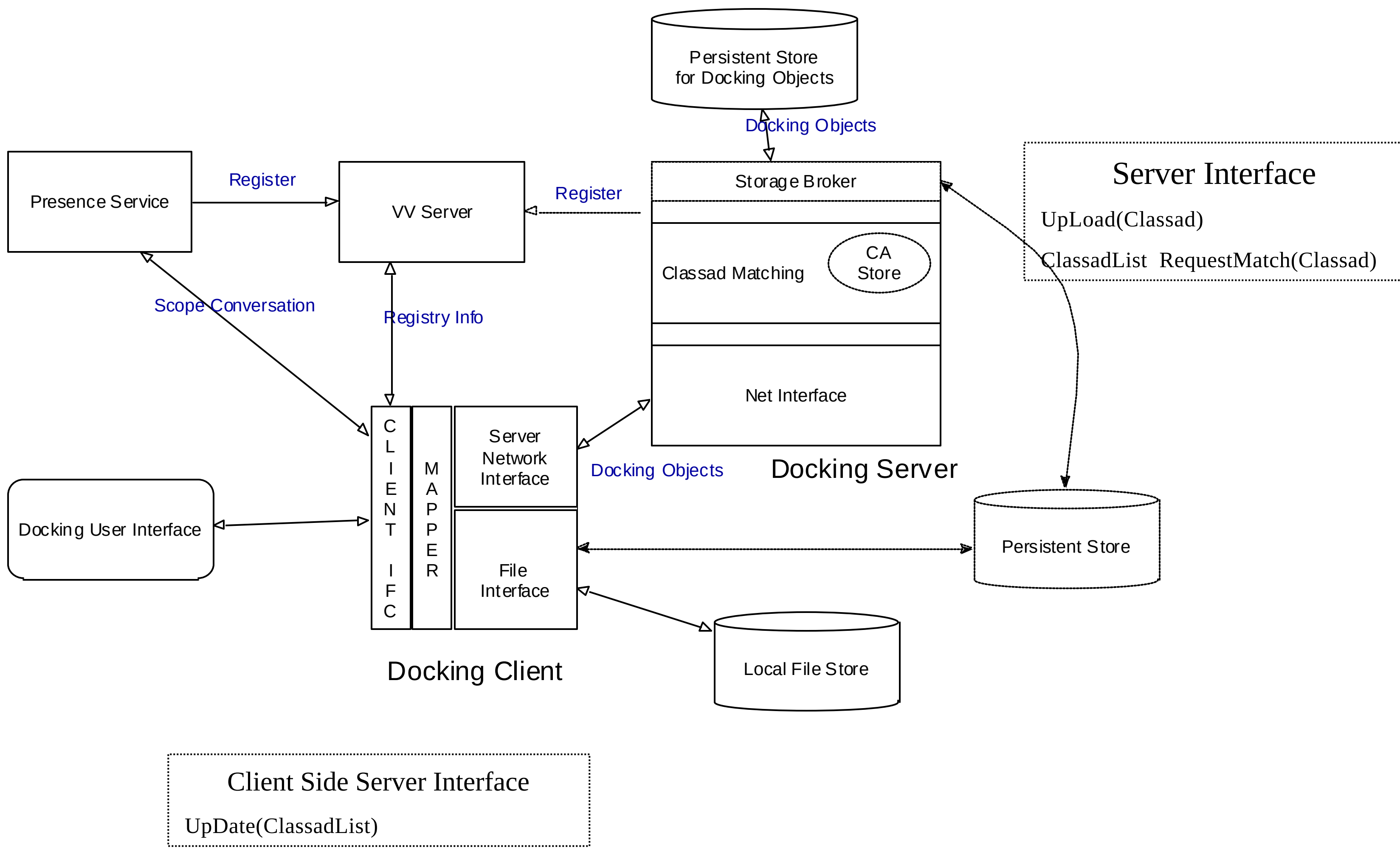
Basic Venues Services

- *Room Entrance*
  - Linkage from one venue to another
  - Defines topology
- *Venue Client*
  - Implemented in venues client code
  - Provides presence information (what nodes are in the venue), capabilities information
- *Media Stream*
  - Encapsulates information about address bindings
  - Active clients can determine multicast connectivity & work around breakages

Other services

- Persistence
  - Use file/object management tools/services to provide venues-bound file spaces
  - For workspace docking
- Network capability negotiation
  - Determine holes in multicast connectivity, mismatches in capacity, etc
  - Build bridging / bandwidth management / transcoding gateways on the fly to build full connectivity

Workspace Docking Architecture



Access Grid Software

- VV server package
- AG Node package
- Beacon and utilities
- Docking software
- Voyager package
- Demonstration applications (dppt, vic/vtk)
- Current release AG v1.3

Access Grid Documentation Project

- Community wide effort to document the Access Grid
- Based on the Linux documentation project
- Lead by Boston University
- Documentation of software, training and user manuals

Scientific Workplace of the Future

- Interlinked collection of “Active Spaces”
  - Project rooms and personal workspaces
  - Virtualization of workspaces (pocket laboratory)
- Pervasive computer mediated support
  - Personal work and JIT learning
  - Group work and virtual organizations
  - Integrated Grid infrastructure
    - WA Grid access to significant experimental resources
    - LA Grid coordinating multiple computing devices and systems
- Pervasive virtualization of services
  - Compute, storage, applications, etc.

Specific Challenges for ACEs

- Three highest-level problems
  - Developing a science of “collaboration”
    - What works and why ? (human factors and social issues)
    - What do we need and how should it be interfaced to the user(s)
  - Development of open extensible research platforms
    - Enabling the community to leverage each others work
    - Explore issues beyond current standards based systems
    - Deployment of large-scale testbeds
  - Integration of ACEs with Grids
    - Define software architectures that support tight coupling
    - Leverage Grid infrastructure where ever possible

Science of Collaboration

- Understanding the benefits of collocation
  - Radical collocation
  - Extreme Collaboration
  - Extreme telecommunity
  - Historical studies of collaborative behavior
- Collaborative interaction taxonomy
  - Structured interactions v Unstructured interactions
  - Ad Hoc use v formal (planned) use
  - Intentional use v unintentional use
  - Social v Work
  - Etc.

Development of Open Platforms

- Access Grid (and friends)
  - Extend AG architecture to enable plug-ins
    - Generalized venue services model
      - Venue based coordination of p2p services and c-s applications
    - Generalize the AG node model to include pervasive room oriented devices and personal devices
      - Tiled displays and handheld devices
      - VR devices, touch screens and scanners
    - Develop AG network services architecture
      - Stream processing and gateways
  - Deploy community testbeds
    - Earth science community is target of Alliance SWOF project
    - Systems biology is emerging target

Integration with Grids

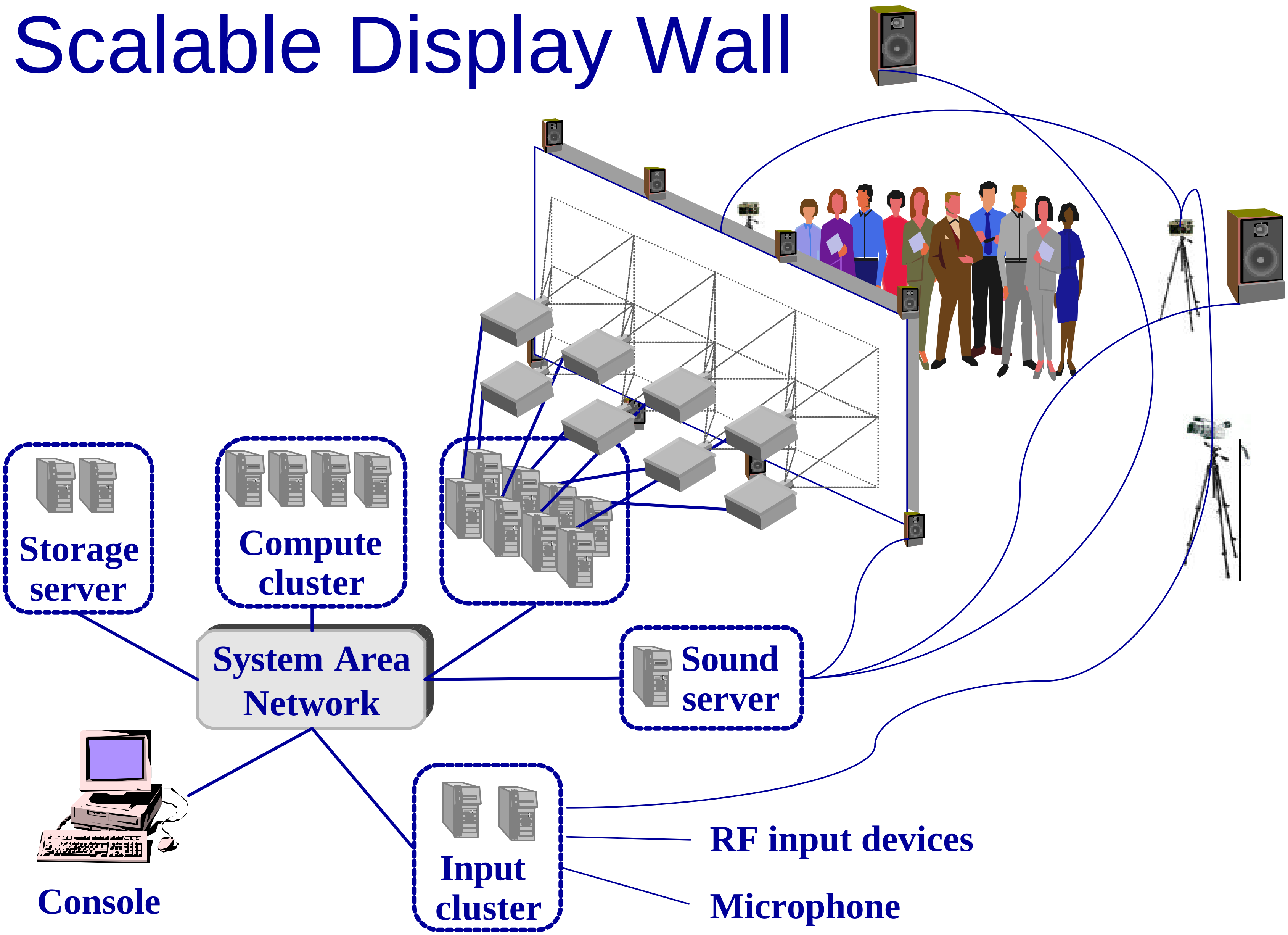
- Developing an appropriate services stack
  - Leverage current Grid technology (e.g. Globus Toolkit)
    - Security, scheduling, meta-services infrastructure
    - Directories, transport, reservations, QoS, etc.
  - Influence new features and functionality
    - Group oriented security models and persistent object security
    - Multicast enabled transport and data distribution
    - Device availability (e.g. portables, handheld, etc.)
    - Local area Grids (e.g room grids)

Active Mural $\Rightarrow$ Beyond the MegaPixel

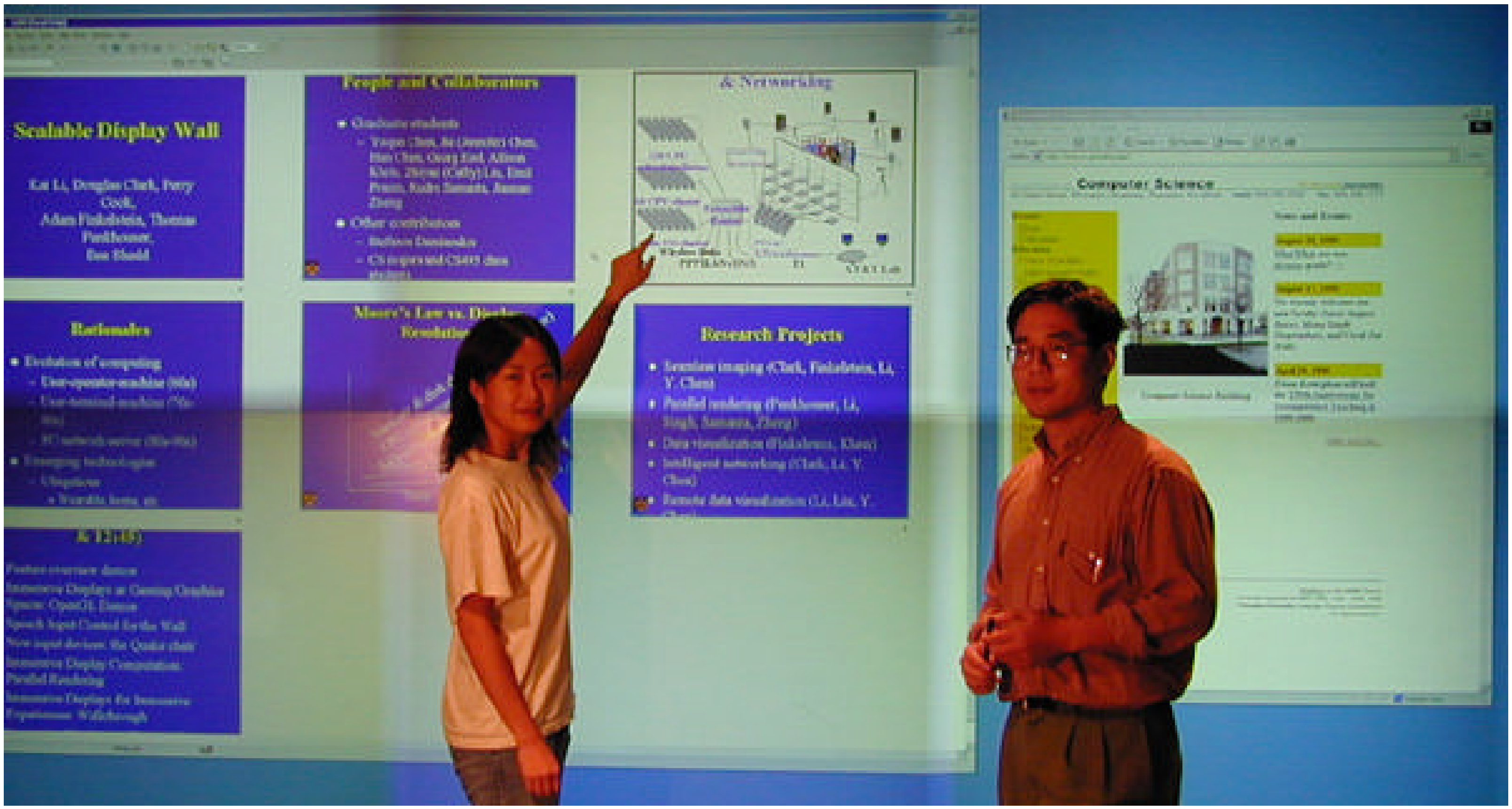
Related Work:

- Stanford's Info Mural (Hanrahan, et al.)
- Princeton’s Scalable Display Wall (Li, et al.)
- MIT AI Lab’s Big Inexpensive Display (Knight et al.)
- Minnesota’s Great Wall of Power (Woodward et al.)
- EVL’s Infinity Wall (DeFanti, et al.)
- UIUC’s SmartSpaces Wall (Reed et al.)
- UNC’s Office of the Future (Fuchs et al.)
- LLNL’s Visualization Corridor (Uselton, et al.)

A Scalable Display Wall



Large Is Good: Window Applications



The Space Station (Princeton)

Fractal Images

Interactive Mural (Stanford)

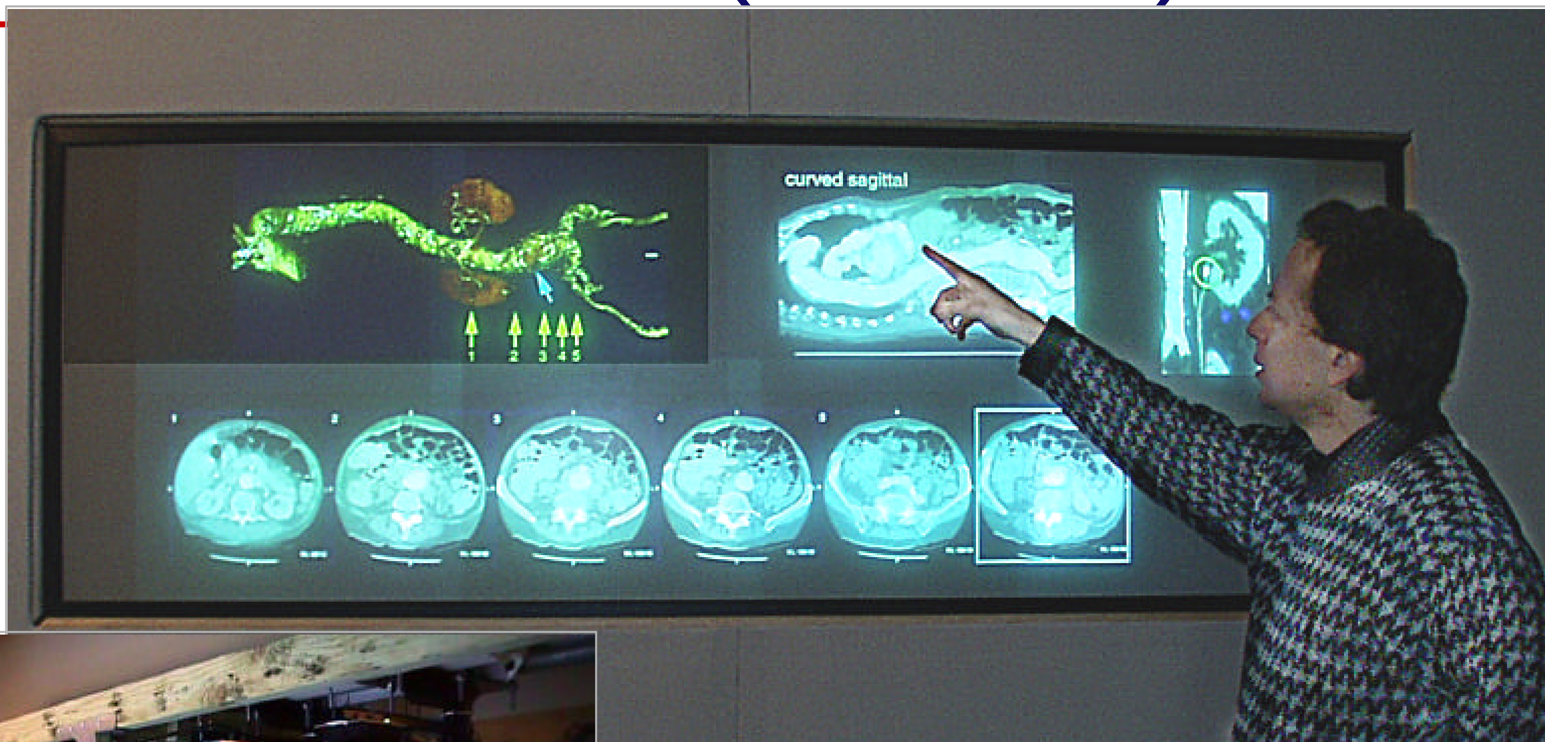


Image and virtual colonoscopy concept courtesy Sandy Napel, Stanford Radiology Department.

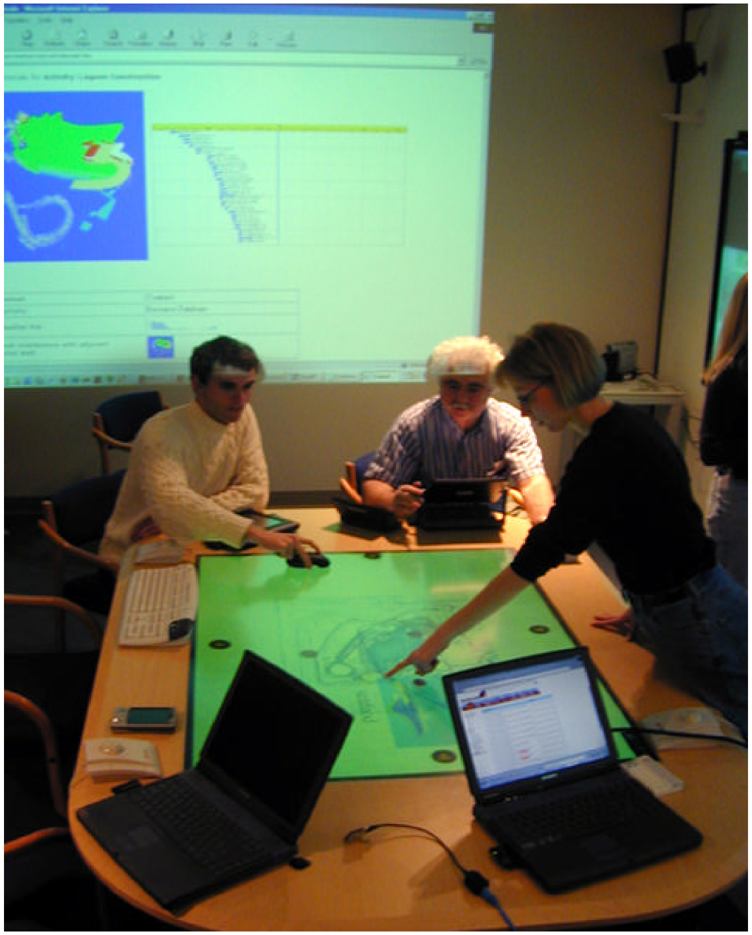
Projectors: 1024x768, 900 ANSI Lumens

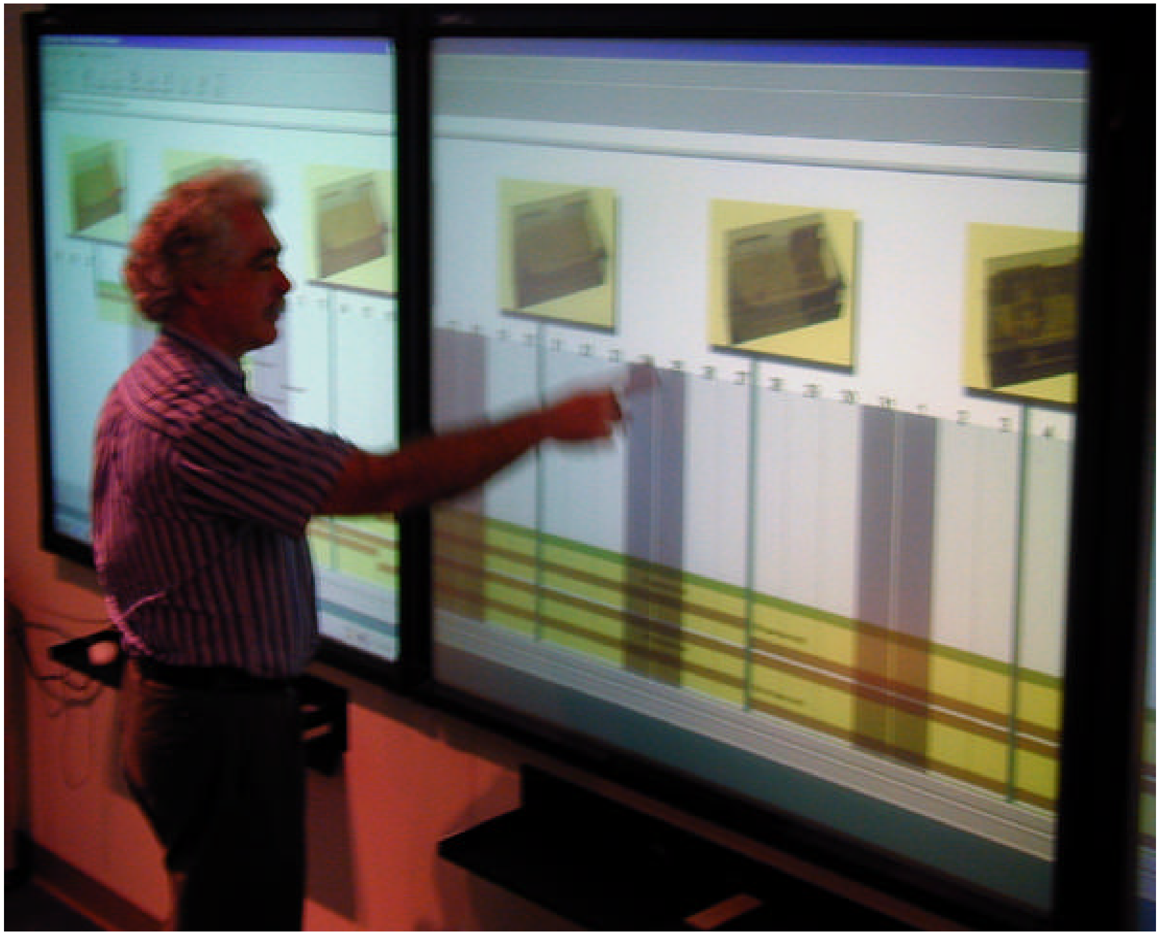
Mural: 6’ x 2’, 4096 x 1536, ~60dpi.

Interactive Mural (SmartBoards)

Interactive Conference Room Table

Project Discussion (Stanford)

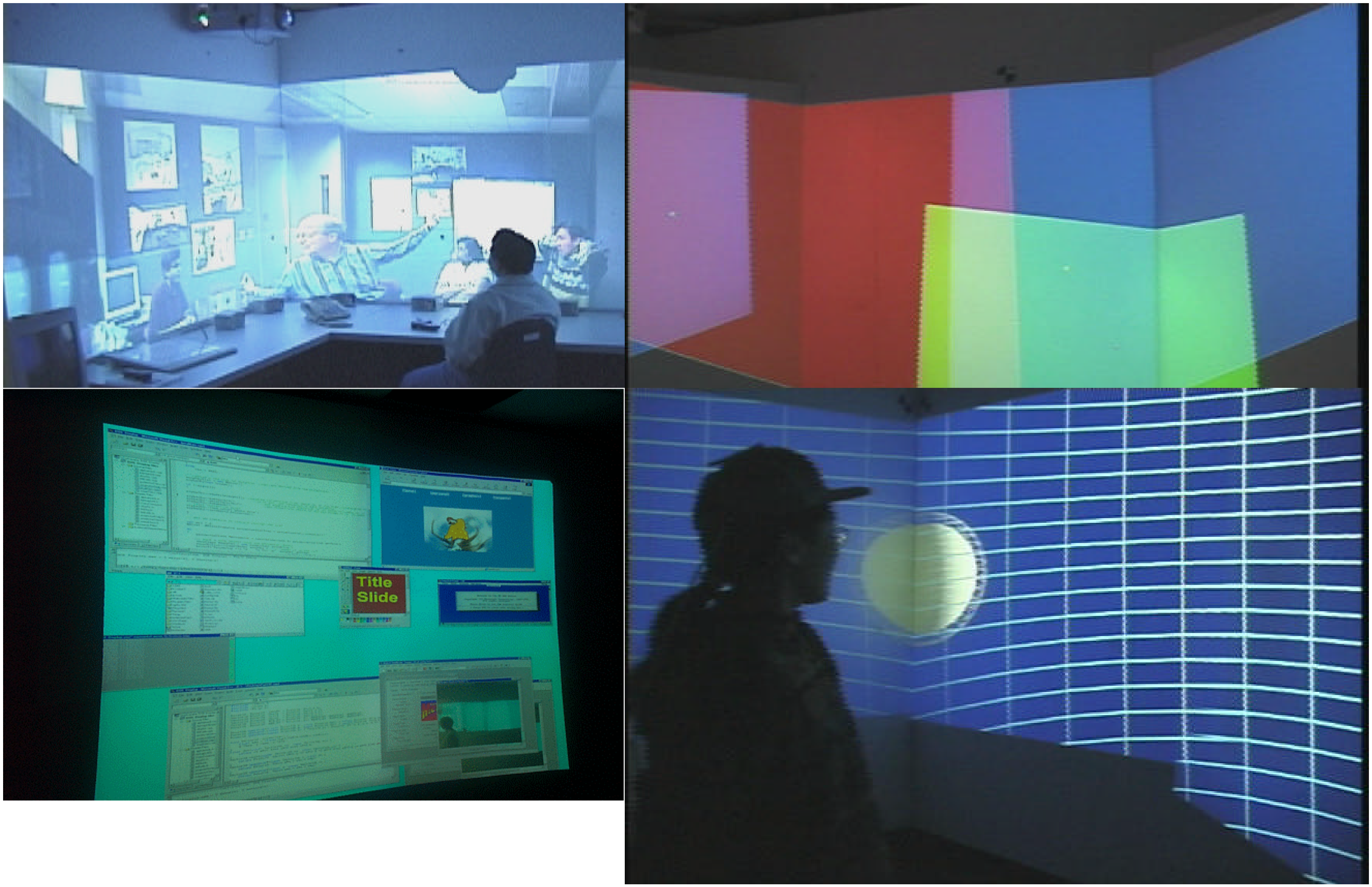




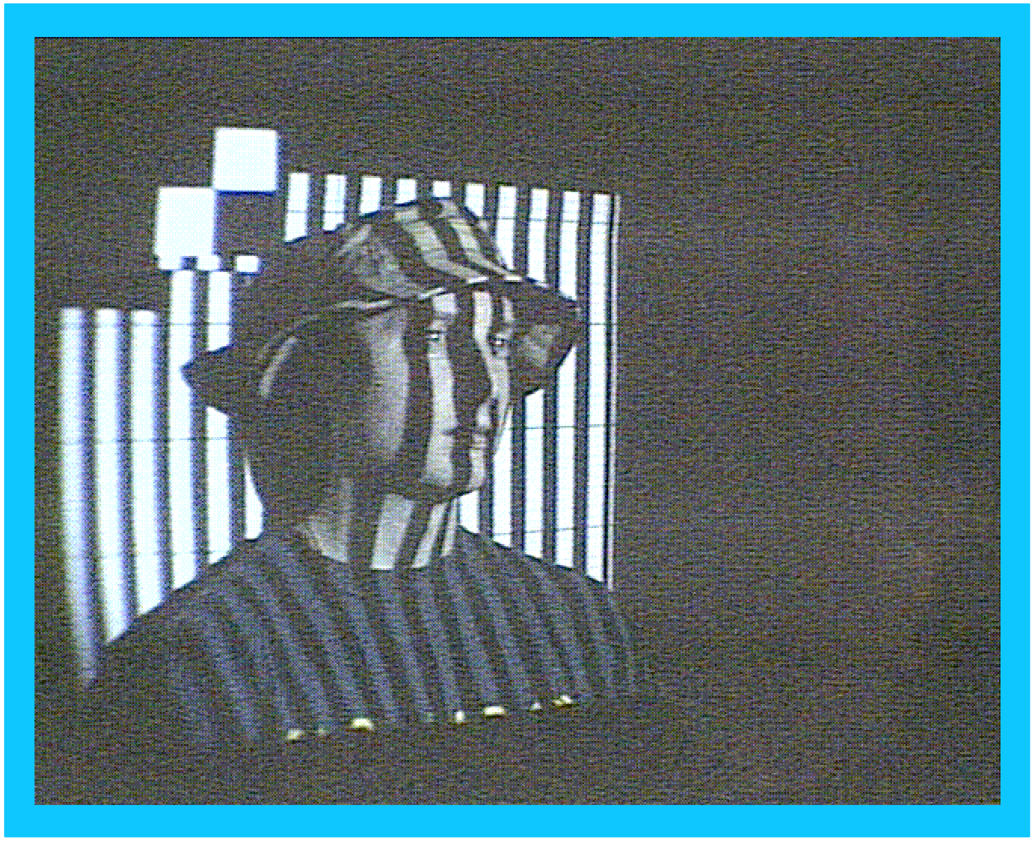
Disney Theme Park Plan

‘Office of the Future’ Vision (UNC)

2D & 3D Overlapping Projectors



Structured Light (UNC)



‘Office of the Future’ 2000

Tele-Immersion Display Devices

Large Rooms and Shared Environments

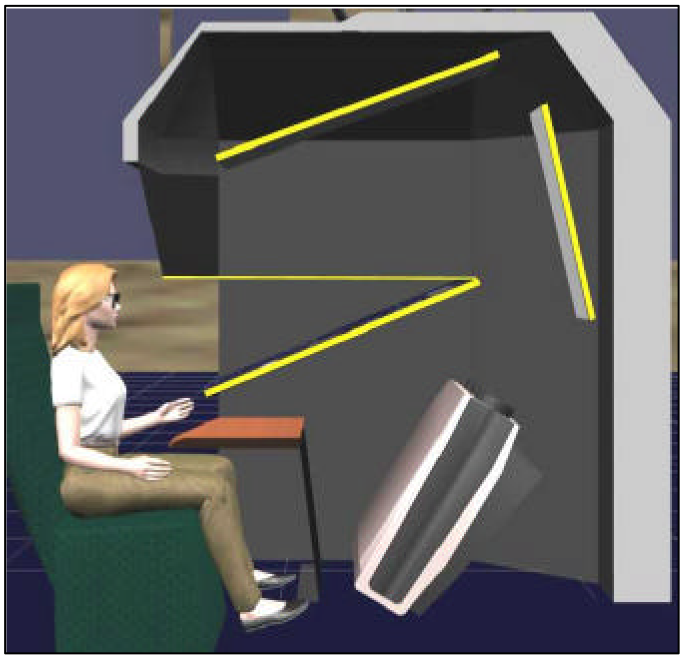
CAVE®

ImmersaDesk2™

1992— First CAVE---------→1999— ~300 ProjectionVR devices

Tele-Immersion Devices (EVL)

Augmented Reality with Gesture and Facial Recognition



PARIS

Personal Augmented Reality Immersive System

Access Grid Network Services

Middleware to extend the Access Grid to a broader range of individuals and groups who may have:

- Limited collaboration infrastructure
- Limited networking capabilities
- Legacy equipment and systems
- New capabilities (e.g. display walls)

Access Grid Network Services

- Extending Access Grid architecture to support arbitrary network services

A network service is a process acting on one or more network streams

Two examples:

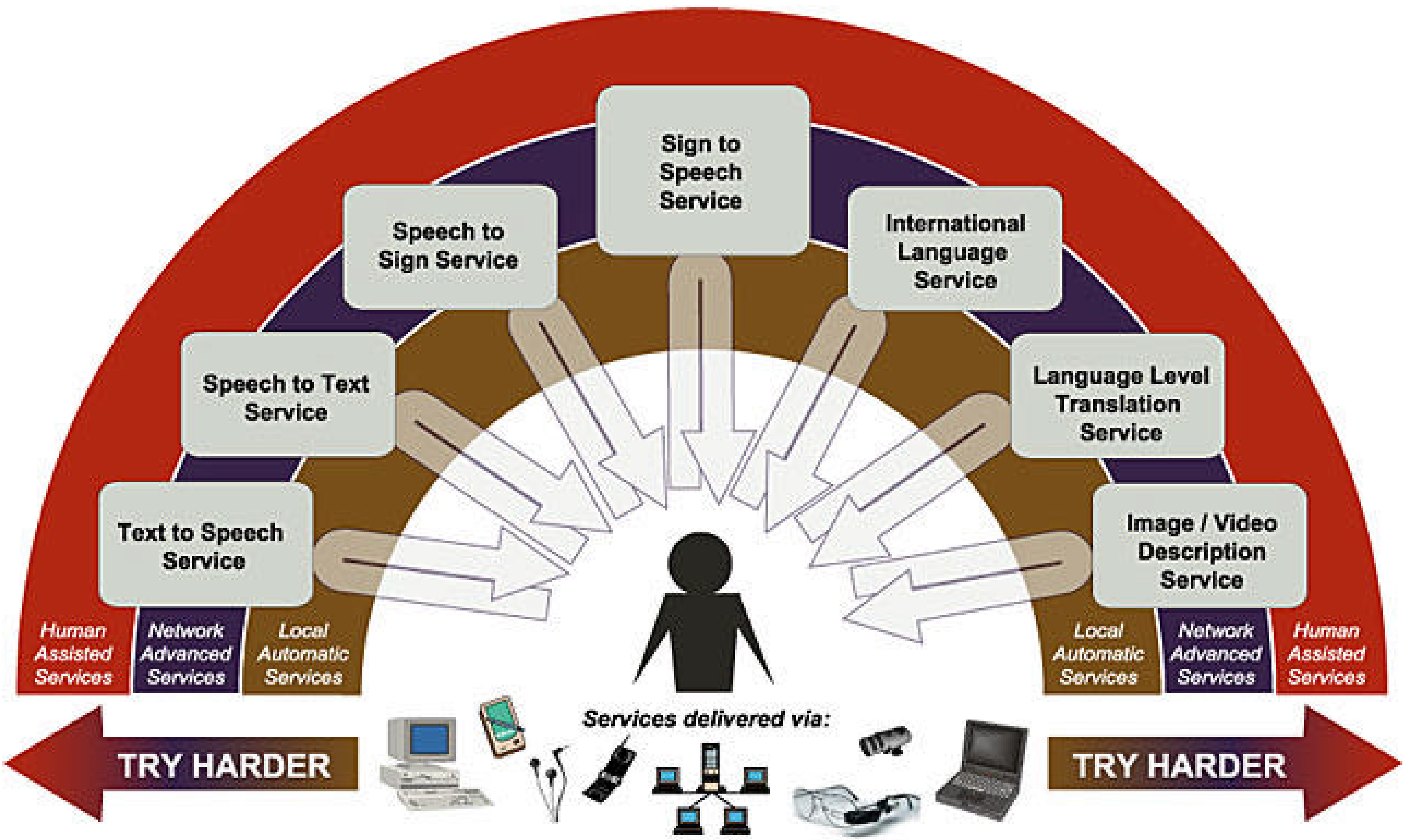
- Audio transcoding service 8KHz – 16KHz
- Video selection service

Examples of AG Network Services

- Multicast address allocation
- Network bridging
- Network audio fallback to phone
- Multicast beacon
- Video subsampling
- Video stream compositing
- Audio stream mixing
- Network audio monitor
- Network audio equalization
- Closed captioning
- Language translation

Modality Translation on the Grid

Background: http://trace.wisc.edu/docs/modality_translation_poster2001/



Challenges

- Extensibility
- Security
- Services management
- Negotiation of capabilities
  - Automatic resolution
  - Transparency
  - Soft failure modes

Planned Development

- Network services engine
  - A virtual venue associated service
- Capability resolution engine
  - Service registry and broker services
- Network services management interfaces
  - UI for administrating network services
- Two reference services
  - Audio transcoder
  - Video selector

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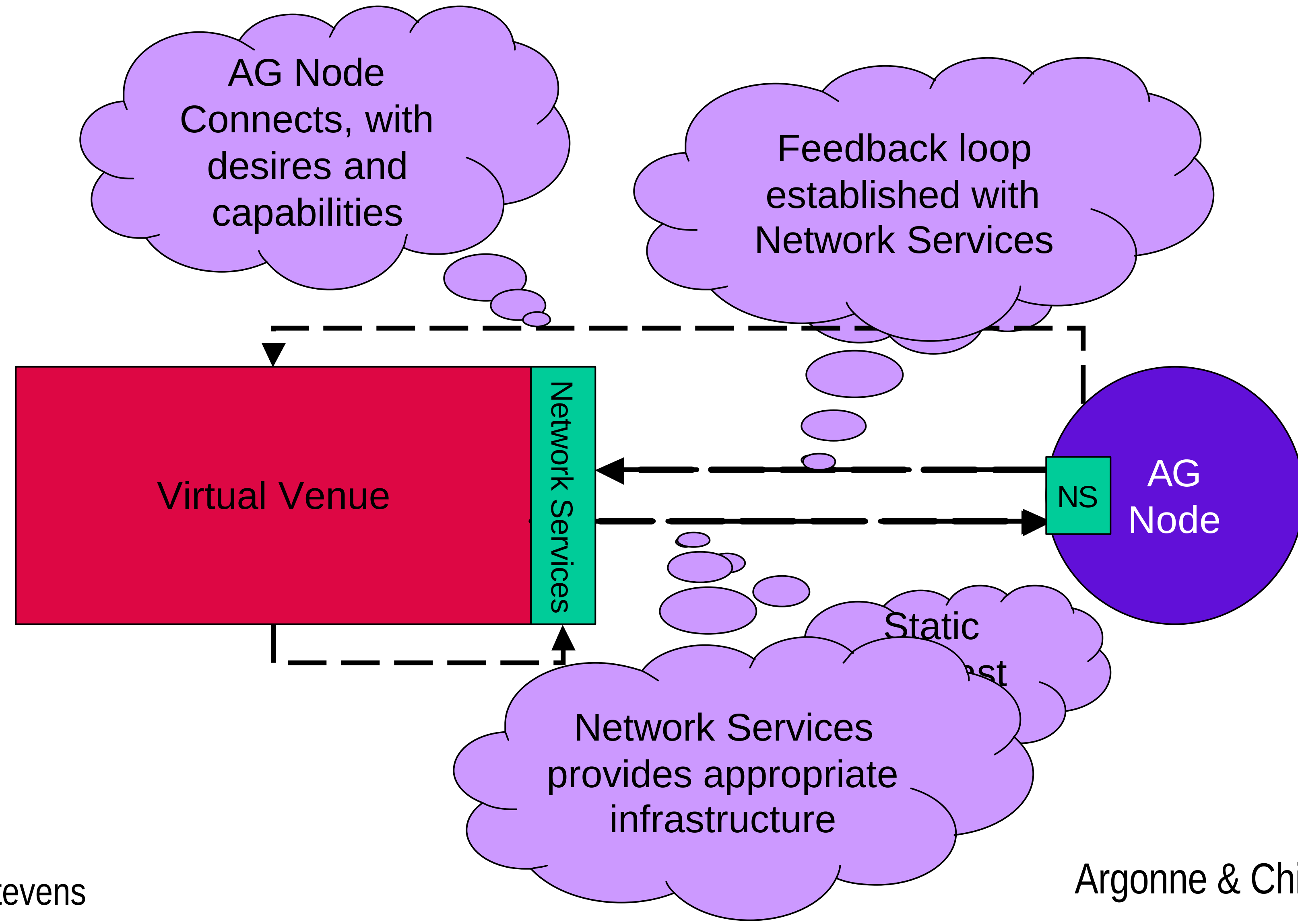
Relationship to the Access Grid



References

- The Access Grid Project
  - www.accessgrid.org
  - www.insors.com
- Conferences and Workshops
  - Access Grid Retreats (next one scheduled with GGF6)
  - Computer Supported Cooperative Work (CSCW) ACM conference www.acm.org
  - Workshop on Advanced Collaboration Environments (WACE) Held annually with HPDC see GGF5/HPDC
  - ACE working group of the Global Grid Forum (www.gridforum.org)
- Journals
  - ACM Multimedia and MIT Press Presence

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